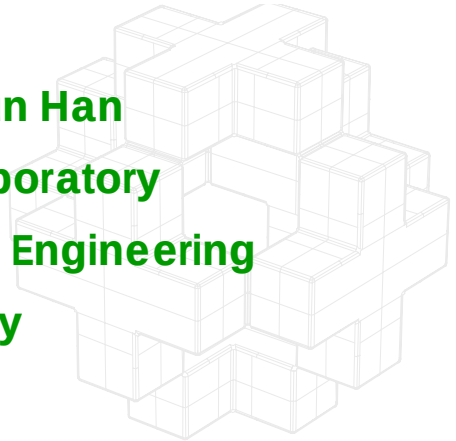
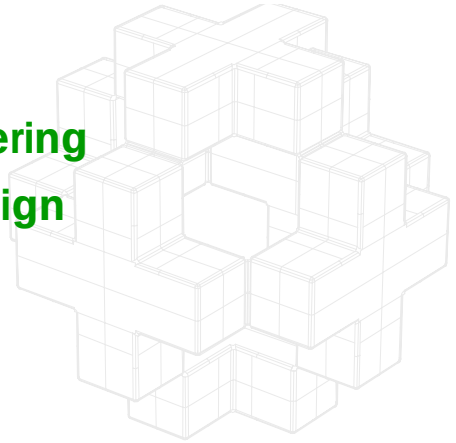
Chemical Product Design

Sungwoo Cho and Chonghun Han
Intelligent Process Systems Laboratory
School of Chemical and Biological Engineering
Seoul National University



PART I. Introduction

- Changes in Chemical Industry & Engineering
- Characteristics of Chemical Product Design

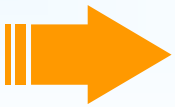


Chemical product design

What is chemical product design ?

Imagine 4 chemically based products

- **An amine for scrubbing acid gases**
- **An electrode separator for high-performance batteries**
- **A pollution-preventing ink**
- **A ventilator for a well insulated house**



These four products may seem to have nothing in common

However,

We begin by defining what we need

We think of ideas to meet this need

We then select the best of these ideas

Finally, we decide what the product should look like and how it should be manufactured

This entire procedure

→ Product Design !!!

Trend of world chemical industry

1950s ~ 1970s

❖ **Growth and diversification era**

- Growth that exceeds GDP growth rate
- Golden age for chemicals
- Focus on commodity chemicals

1970s ~ 1980s

❖ **Restructuring and globalization era**

- Growth has slowed : high competition & low profitability
- Economy of scale : large volume production
- Restructuring & consolidation
- Transfer of manufacturing plant and Asian development

1990s ~ 2000s

❖ **Specialization era**

- Discovery of new technology : NT, BT
- New paradigm : Value Preservation → Value Creation
- Some company : focus their growth on chemical products.

Trend of world chemical industry

Changes in the chemical industry

Fiber	1948	1969	1989
Cotton, Wool	**4353**	**4285**	**4794**
Synthesis	**92**	**3480**	**8612**

Growth of textile fibers (10^6 lbs/year)

Source: Spitz(1998); U.S. Department of Commerce

From 1950 to 1970 the chemical industry produced ever increasing amounts of synthetic textile fibers. Over these decades, while the production of natural fibers was about constant, the production of synthetic grew 20% per year.

However, from 1970 to 1990, the synthetic textile fibers grew by less than 5% per year. At this time, the industry stayed profitable by using larger and larger facilities.

→ Bigger profits came from consolidating production into bigger plants, designed for greater efficiency in making one particular product.

Stay Profitable ?

1. Leave chemical business
2. Focus exclusively on commodities
3. Focus their growth on specialty chemicals

→ Many chemical companies are turning focus to specialty chemicals. ex) Kodak, 3M

Trend of world chemical engineering

K. M. Ng, "MOPSD: a framework linking business decision-making to product and process design," *C&CE*, **29**, 51-56 (2004).

1970s

❖ **Improvement of equipment and process performance**

- Building on a better understanding of transport phenomena, and improved simulation and optimization techniques.

1980s

❖ **Pinch technology and advanced control**

- Pinch technology to minimize energy consumption.
- Advanced control to maximize productivity.

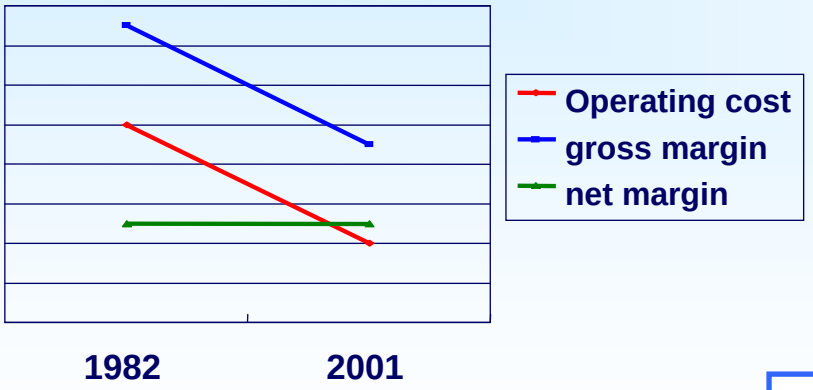
1990s

❖ **The entire supply chain for additional savings**

- Aspentech, SAS, PricewaterhouseCoopers
- Offering a wide range of tools for enterprise resource planning, demand, production and distribution planning, etc.

Trend of world chemical engineering

cost for downstream petroleum processing in the US



C. J. Kim, "Supply chain management in process industry," *Keynote presentation at PSE Asia*, Taipei, 2002.

Due to competition, the gross margin has also decreased by the same magnitude

=> resulting in no gain in net margin

K. M. Ng, "MOPSD: a framework linking business decision-making to product and process design," *C&CE*, **29**, 51-56 (2004).

2000s

- **The cumulative effects of research**
  : Ultra-efficient companies for commodity chemicals
  - Few people is needed but profit remains good.

- **The design and manufacturing of differentiated products**
  - View of the profit margin
    Most chemical companies : 8%
    Specialty chemical and pharmaceutical companies: 12% and 20%
  - Shift from commodity chemicals to chemical products

New trend of chemical industry

Changes in the chemical company: ICI

ICI: British chemical company

- **1920s ~ 1990s**
  - Mainstay of Bulk chemical industry
  - Products: Commodity chemicals

    Ex) Polyester, ethylene, fertilizer, etc.

- **Present**
  - Late 1990s: shift from commodities to chemical products
  - Products: Chemical products

    Ex) Perfume, flavorings, and coatings for electronics engineering.

New trend of chemical industry

2004

	Product	Sales	Sales Ratio	Location
National Starch	Starch	1870 m₤	33%	USA
Quest	Flavor fragrance	584 m₤	10%	Netherland
Uniqema	Surfactants oleo chemicals	629 m₤	11%	Netherland
Paints	Paint, coating	2161 m₤	39%	UK
Regional & Industrial	Commodity chemicals	375 m₤	7%	Pakistan, India, Argentina
Total		5619 m₤	100%	

- Chemical product is the major product in ICI.

- Manufacturing plants for chemical product are located in the developed countries such as USA, UK, and Netherland. However manufacturing plants for commodity chemicals are located in the developing countries such as Pakistan, India, and Argentina.

New trend of chemical industry

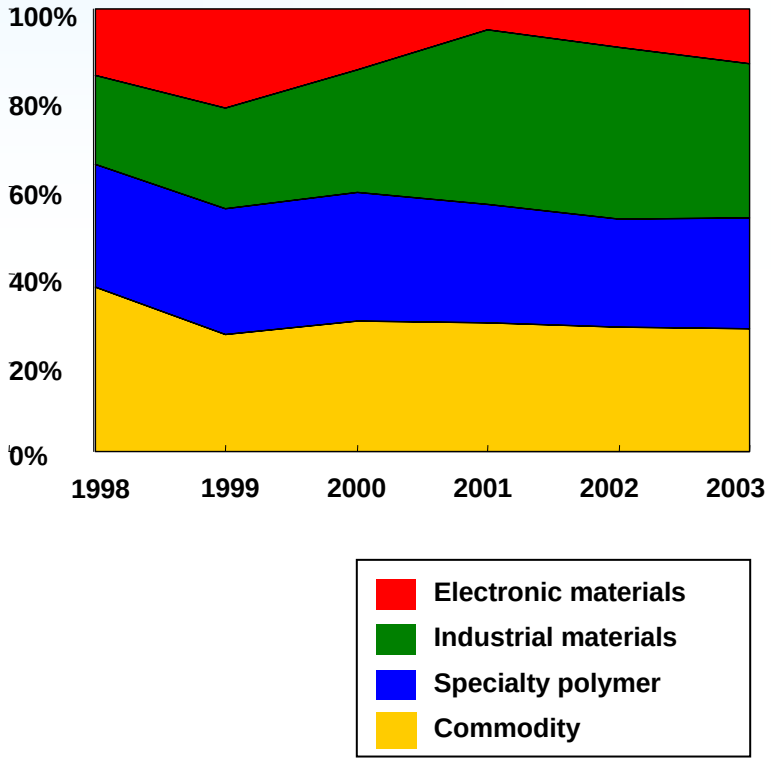
Changes in the chemical company

Foreign

Company	Results
3M	❖ Composite conductors are deliver up to 3 times more power ❖ 2003 R&D 100 Award Winner for Innovation
Kodak	❖ Sustainable development promotes environmentally- conscious product design ❖ The Queen's Award Enterprise
Dow	❖ Develop "Real" with wood and metal ❖ Maintain the world plastic leader ❖ Preoccupy many application fields

Korea

Sales ratio of chemical company

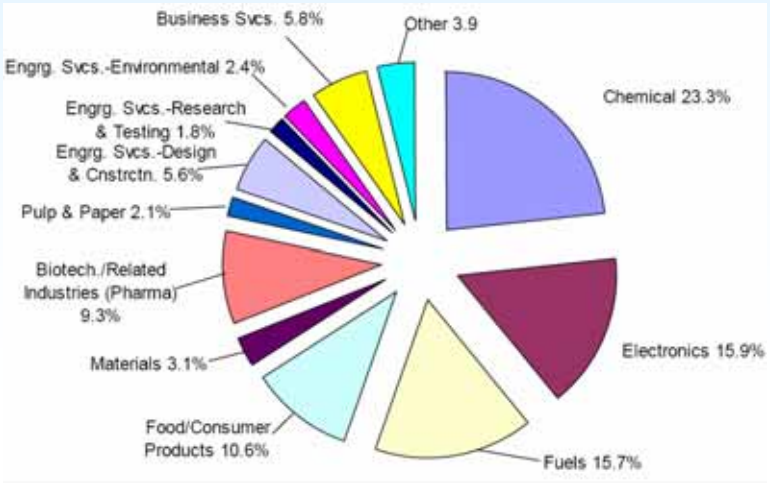


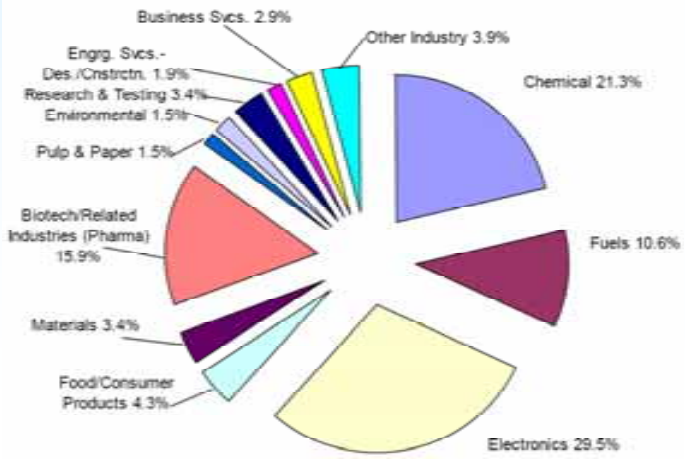
New trend of chemical industry

Changes in employment

I. E. Grossmann, “Challenges in the New Millennium: Product Discovery and Design, Enterprise and Supply Chain Optimization, Global Life Cycle Assessment,” *Computers and Chemical Engineering*, **29**, 29-39 (2004).

Distribution of 2000-2001 industry placements of B.S. and Ph.D. graduates in the US





At the B.S. level chemicals, fuels and food/consumer product companies hired almost 50% of the students. Electronics hired as many as the fuels companies (16%), while the share of biotechnology and pharmaceutical, and engineering services and consulting, was close to 10% for each.

At the Ph.D. level the trends are similar, although chemicals, fuels and consumer products show a share of only 35%, which is slightly above electronics at 30%. Also biotechnology and pharmaceuticals has a 16% share.

New trend of chemical industry

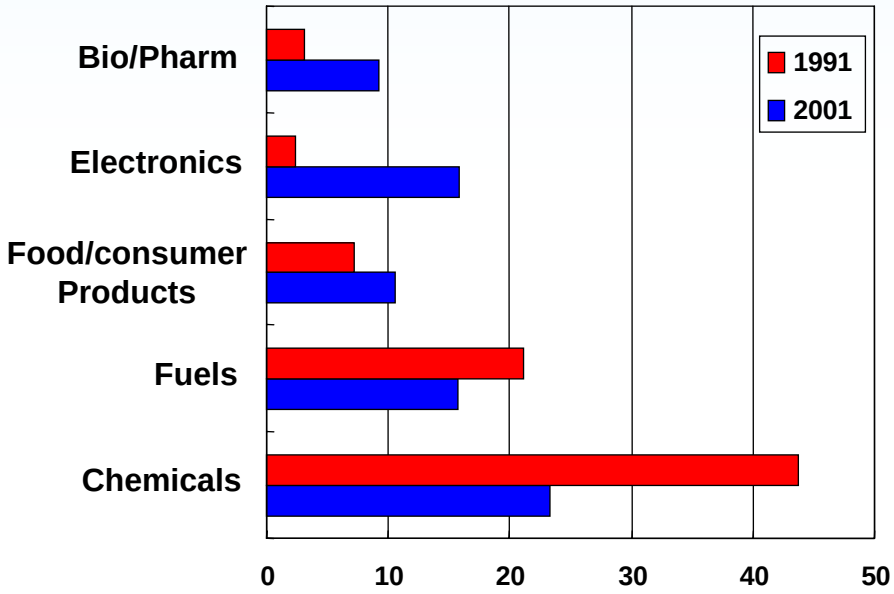
Changes in employment

A. W. Westerberg and E. Subrahmanian, “Product Design,” *Computers and Chemical Engineering*, **24**, 959-966 (2000).

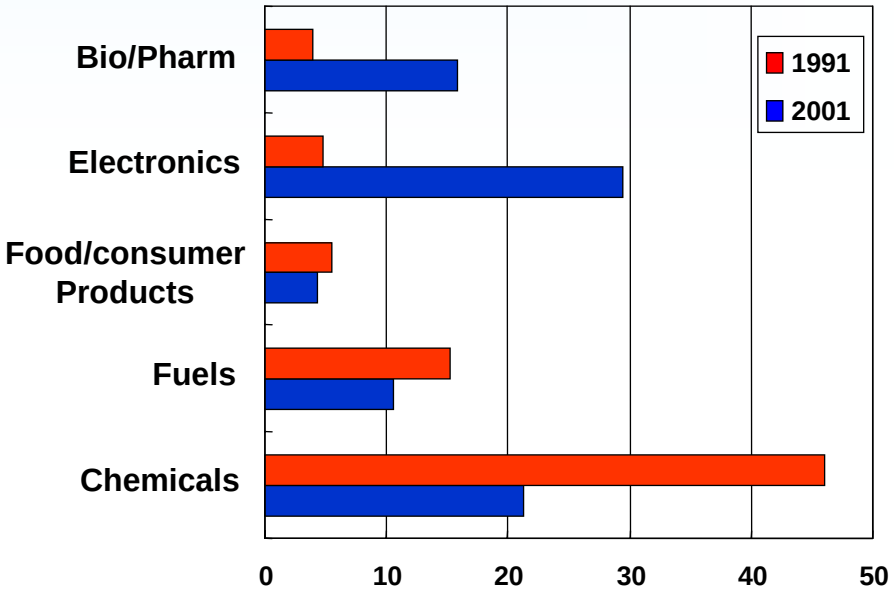
E. L. Cussler and J. Wei, “Chemical Product Engineering,” *AIChE Journal*, **49**, 1072-7075 (2003).

Distribution of industry placements of B.S. and Ph.D. graduates in the US

B.S.



Ph.D.



=> About half of the chemical engineer are entering product-oriented companies.

New trend of chemical industry

Changes in what chemical engineers do

The emergence of products as a focus for chemical engineers implies change in what chemical engineers do.

Past

- **Limit thinking to chemical engineering**
  - Reaction engineering
  - Unit operation

Present

- **New role for chemical engineer**
  - Waiting for the marketing division to tell what chemicals needed to be made.
  - Waiting for the marketing division to tell what amounts needed to be made.

Characteristics of product design

Product design

- **Affects all people in the world**
  - Changes and improves people's lives
  - A strong determinant in national standards of living
- **Fundamentally drives our economic system by**
  - Providing the link between what people need and want (marketing) and what an enterprise can make (production)
  - Providing the link between new knowledge on what is impossible (research) and new useful objects (product)
- **Is highly creative**
  - The output never existed before
- **Is highly complex**
  - Involves the linked contributions of many different skills

Characteristics of product design

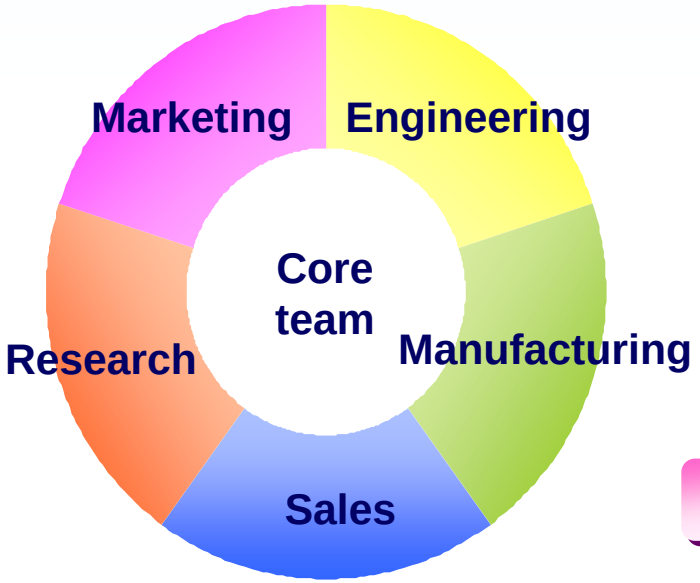
Product design

- **Is highly evolving**
  - Learns from the past, anticipates the future, subject to rapid change, highly timing dependent
- **Can be esthetically pleasing**
  - the product
  - sometimes the process
- **Is iterative process**
  - Assessment and refinement
- **Invariably involves multivariate trade-offs**
  - Between the other performances
  - Between time and performance
  - Between cost and performance

Characteristics of product design

Product design

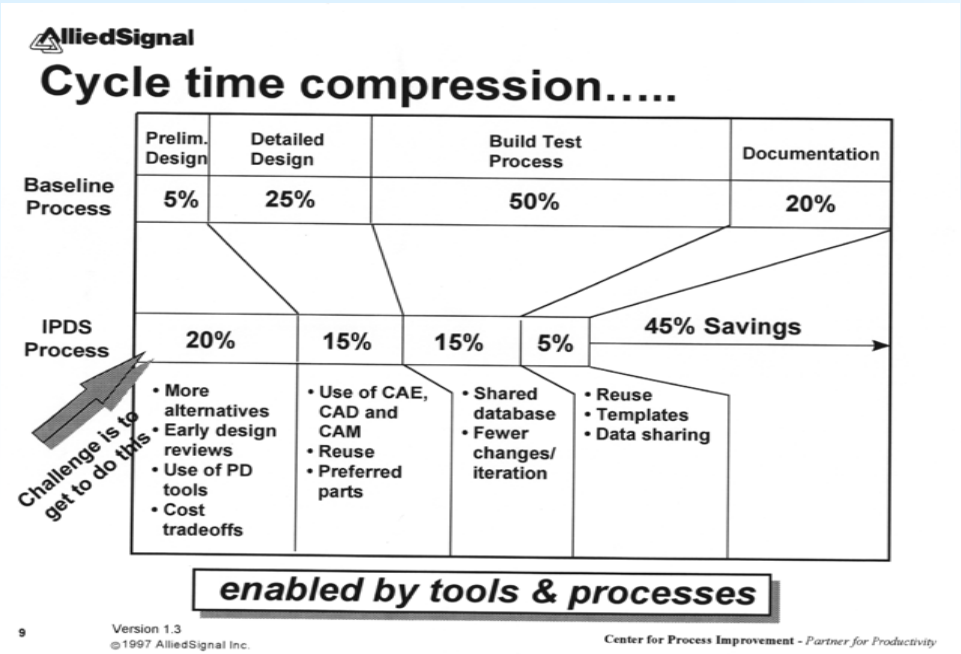
- **Is accomplished by project team**
  - Due to the complexity of multidisciplinary process
  - Work apart, coming together periodically to compare notes and keep the entire team informed of process
  - Core team and extended team

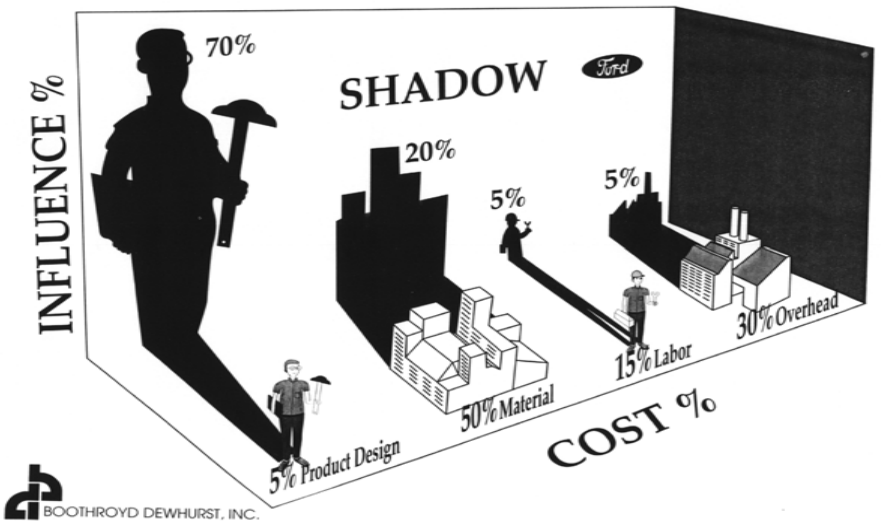


Chemical product design project team

Characteristics of product design

Product design effect



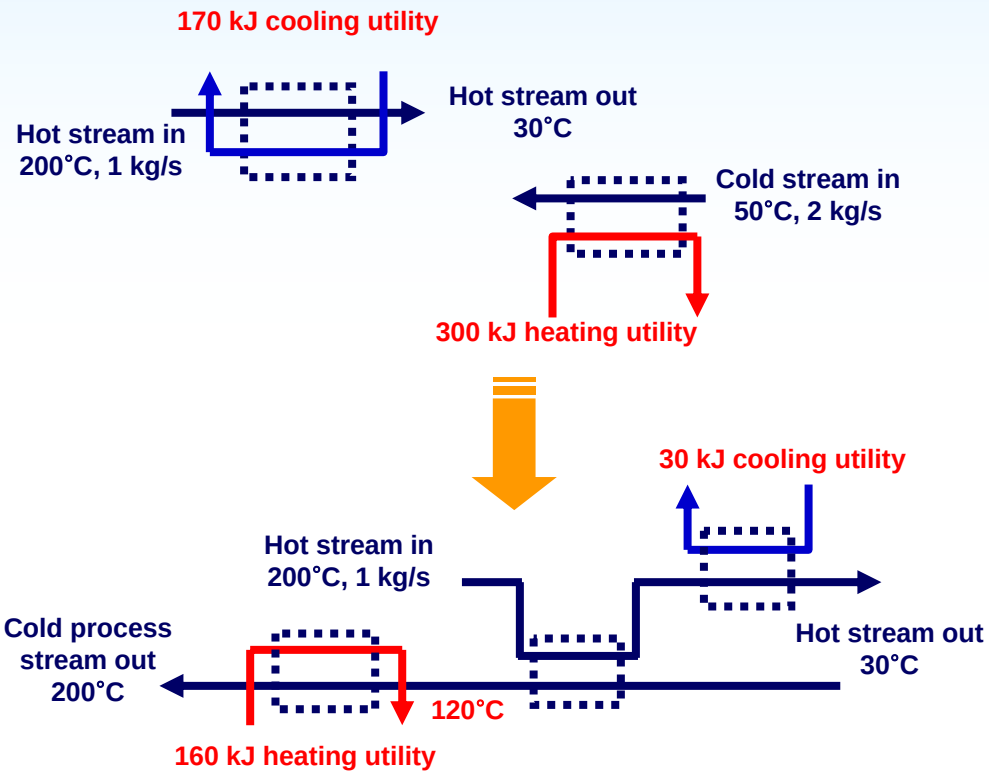


=> Effect of product design is considerable.

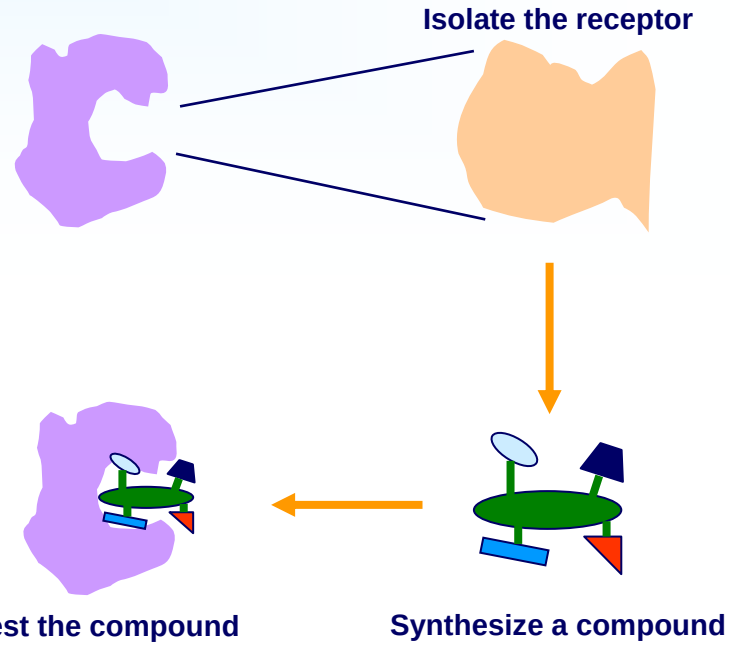
Characteristics of chemical product design

Differences between product design and process design

Process design

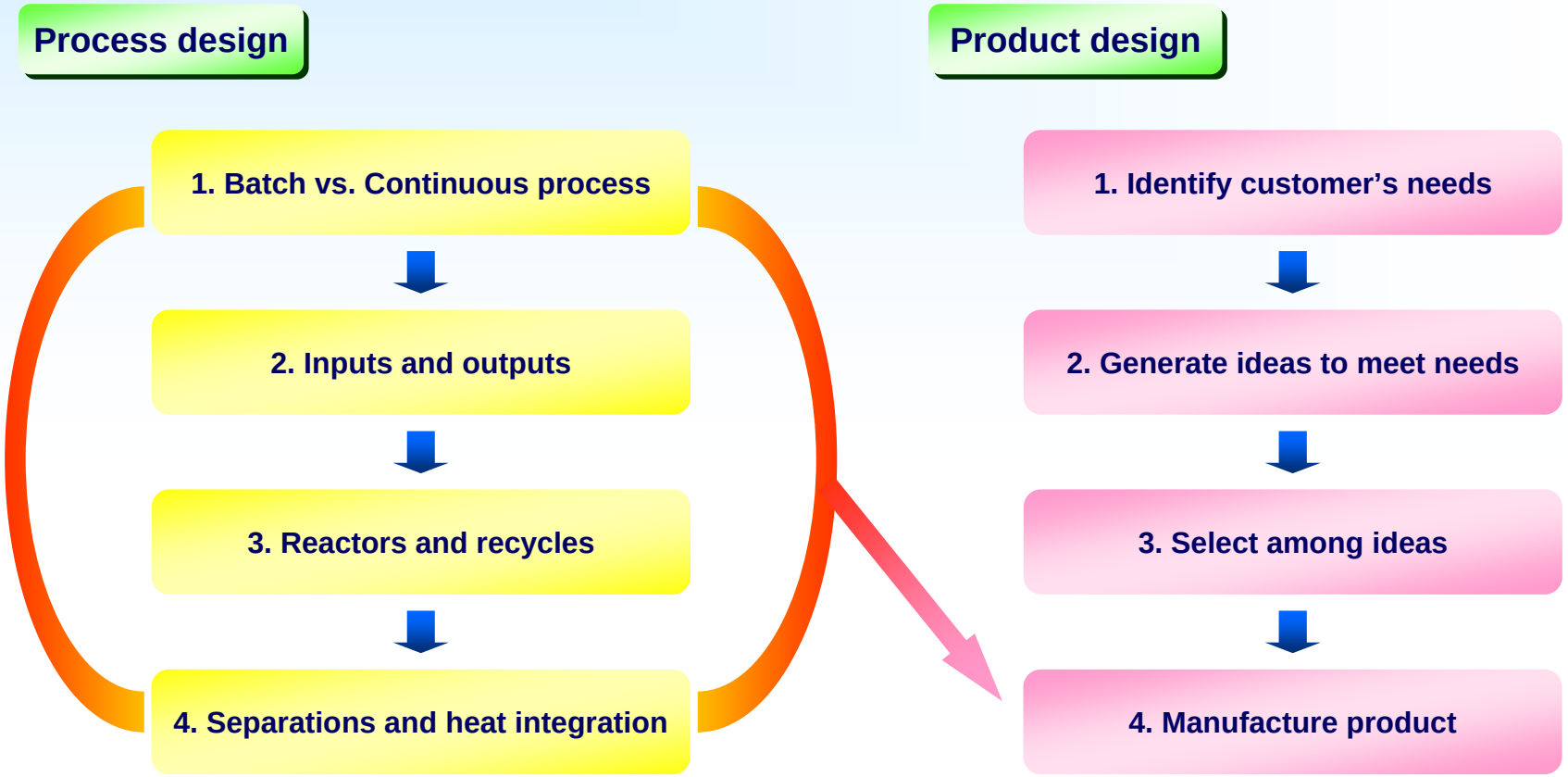


Product design



Characteristics of chemical product design

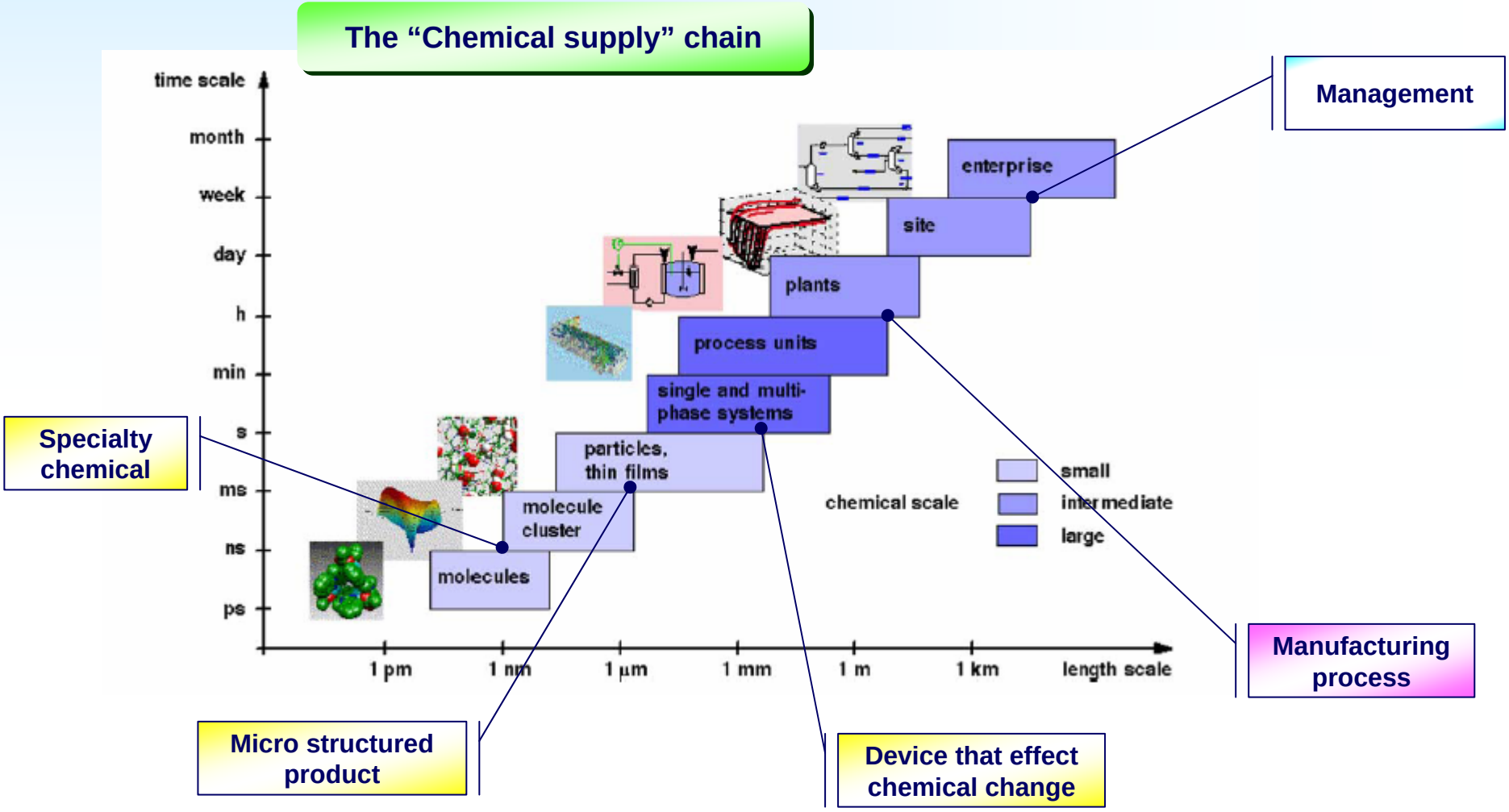
Differences between product design and process design



The manufacturing includes all of the process design hierarchy

Characteristics of chemical product design

Scope of chemical product design



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